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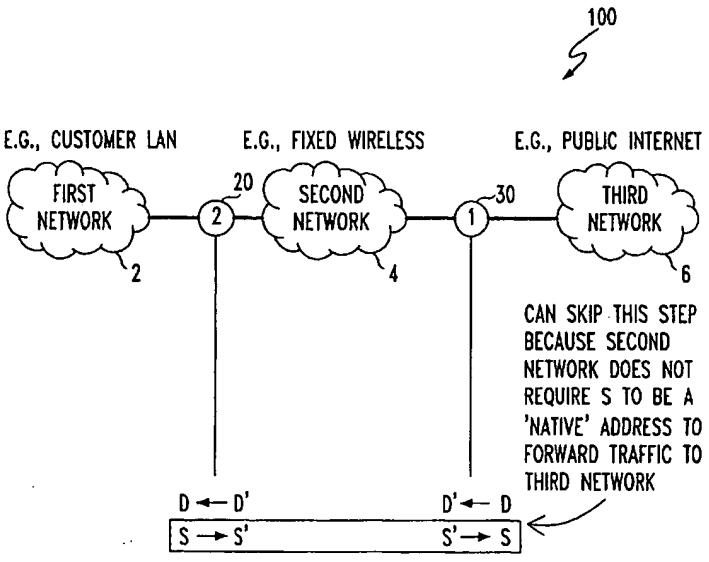
(54) Title: METHOD FOR PROVIDING TRANSPARENT PUBLIC ADDRESSED NETWORKS WITHIN PRIVATE NETWORKS



KEY:

D= DESTINATION ADDRESS IN IP DATAGRAM
S= SOURCE ADDRESS IN IP DATAGRAM
[D,S]= GLOBALLY UNIQUE IP ADDRESSES
[D',S']= NON GLOBALLY UNIQUE IP ADDRESSES
☐ = OPTIONAL STEP

ASSUMPTIONS:

- FIRST NETWORK AND THIRD NETWORK USE GLOBALLY UNIQUE ADDRESS

- SECOND NETWORK USES NON GLOBALLY UNIQUE ADDRESSES

(57) Abstract: A system includes a first device for receiving a datagram from a public network whose destination is specified by a globally unique Internet Protocol (IP) address and for performing network address translation of said globally unique IP address to a non-globally unique IP address in a private network; and a second device for routing said datagram to a user device connected to the second device wherein said user device includes the destination specified by said non-globally unique IP address and for performing basic network address translation to said non-globally unique IP address to said corresponding globally unique IP address.

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METHOD FOR PROVIDING TRANSPARENT PUBLIC ADDRESSED NETWORKS WITHIN PRIVATE NETWORKS

FIELD OF THE INVENTION

This invention relates generally to computer network connections to the Internet or any public or private network requiring unique end station addresses and more particularly to systems and techniques for passing data between public and private networks using network address translation.

BACKGROUND OF THE INVENTION

As computers become more readily available, people (users) are more willing to use computers to communicate and perform their daily tasks. Typically computers are used for electronic mail, Internet access and sharing data. As computers become more prevalent, a greater number of connections to the Internet are required. Furthermore, computers are now coming in different sizes and shapes including personal data assistants (PDAs), smart pagers and smart cell phones which add to the need for fast readily access to a network service provider.

In order for users using a computer to access the Internet and the World Wide Web (WWW), their computer must be connected to one of the hundred or so service providers. Most service providers connect using a protocol known as the Internet Protocol (IP). The Internet Protocol uses a unique address within a computing environment to distinguish among the millions of computers connected to the Internet. An IP address is currently specified by a 32-bit host

address usually represented in dotted decimal notation (e.g. 171.10.9.4). The IP address format is now well known in the art of computer networking. Because of the present Internet 32-bit addressing scheme, only a total of 2^{32} (4,294,967,296) unique IP addresses are possible for the entire (i.e., global or public) Internet. To overcome this limitation, Internet service providers will typically assign each company or organization a single IP address or in some cases a small set of IP addresses which are unique. In addition to unique IP addresses, certain IP addresses are reserved as non-unique IP addresses to be used for private networks. These non-unique IP addresses are not used in the public network.

In order for users to access WWW servers, and the like, IP addresses must correctly and uniquely identify the source and target of data packets. More specifically, IP addresses allow transmitted IP data packets called datagrams, to be self-contained, independent entities of data carrying sufficient information to be routed from the source to the destination computer without reliance on earlier exchanges or the transporting network. A router is a dedicated computer platform whose sole function is to forward packets (i.e., units of transmitted data) between networks. Each stub router (meaning a router that connects a private network to a public network) executing network address translation (NAT) features allow a non-unique IP address to be used within a company and unique IP addresses to be used outside of the company. The latter increases the number of computers that can be connected to the Internet. The non-globally unique IP addresses can be found in IETF RFC1918 and include 10.0.0.0 - 10.255.255.255 (a single class A network), 172.16.0.0 - 172.31.255.255 (16 contiguous

class B networks) and 192.168.0.0 - 192.168.255.255 (256 contiguous class C networks).

As the number of private and public networks increase, the difficulty of accommodating the number of computers also increases. Therefore, what is needed is a system and method for network address translation that would extend a public network across a private address network to facilitate the number of computers that can be connected to the Internet and to allow orderly topology-based routing to the computers via the private address network.

SUMMARY OF THE INVENTION

A system includes a first device for receiving a datagram from a public network whose destination is specified by a globally unique Internet Protocol (IP) address and for performing network address translation of said globally unique IP address to a non-globally unique IP address in a private network; and a second device for routing said datagram to a user device connected to the second device wherein said user device includes the destination specified by said non-globally unique IP address and for performing basic network address translation to said non-globally unique IP address to said corresponding globally unique IP address. With such an arrangement, a system is provided wherein a public network can be extended across a private address network to facilitate the number of computers that can be connected to the Internet and to facilitate orderly topology-based routing to the computers via the private address network.

In accordance with a further aspect of the present invention, the second device is adapted to initially assign an IP address of the private

network to a user device and is adapted to handshake with a registration server to proxy register with an internet service provider to select an IP address of the public network and replace the IP address of the user device with the IP address of the public network. With such an arrangement, datagrams from a public network can transverse a private network without the additional bandwidth required using virtual private network methodology.

In accordance with a still further aspect of the present invention, the system includes a local network connected to the user device, the user device being assigned a globally unique IP addresses, the local network being assigned a set of non-unique IP addresses, a local network device adapted for performing network address translation from the local network to the corresponding public network. With such an arrangement, existing local private networks can connect to a public network across a common carrier private network.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing features of this invention, as well as the invention itself, may be more fully understood from the following description of the drawings in which:

FIG. 1 is a sketch of a local network connected to a private network which is connected to a public network according to the invention;

FIG. 1A is a block diagram of a local network connected to a private network which is connected to a public network according to the invention;

FIG 2 is a block diagram of a computer to implement the invention;

FIG. 3 shows the layer-3 architecture and protocol stacks according to the invention;

FIG. 3A shows the transaction flow diagram for a new customer turning on their workstation for the first time prior to having chosen an ISP service provider;

FIG. 4. shows the transaction flow diagram for an existing customer turning on their workstation after having chosen an ISP service provider;

FIG. 5 shows the transaction flow diagram for a registered user turning on their workstation after having chosen an ISP service provider; and

FIG. 6 is a sketch of a private network connected to a public network which is connected to a corresponding private network according to an alternative embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Before providing a detailed description of the invention, it may be helpful to review the state of the art of Internet access within networks. In a typical private network, each workstation (computer or user device) within the private network is assigned an IP address which has only a local significance. If the number of workstations is greater than the number of globally unique IP addresses assigned to the local network, which is typically the case, there must be a mapping of the locally significant IP addresses to one of the globally unique IP addresses. If a user on a first workstation initiates an outbound session

(e.g., HTTP, or any connection involving the exchange of datagrams), it transmits data, for example, with a source IP address of 10.0.0.2 (i.e., its own locally significant IP address) and a destination IP address of 162.24.16.3 (e.g., an IP address of a target host). The stub router (meaning the router that connects the private network to the public network) maps (i.e., translates) the source IP address to one of the organization's available globally unique IP addresses (e.g., 171.10.9.4) before forwarding the packet to the service provider's router.

If a reply should come back (i.e., inbound), it would contain a source IP address of 162.24.16.3 and a destination IP address of 171.10.9.4. The stub router would then translate the destination IP address to 10.0.0.2 and forward the datagram to the corresponding workstation so that the original session (and thus user) on the workstation can receive their reply. As one skilled in the art will appreciate, the stub router can correctly route subsequent reply datagrams through the address binding, lookup and translation phases of the particular NAT algorithm employed.

It should be appreciated that it may be desirable to connect to a particular service provider though another network. With the introduction of various new High Speed Data (HSD) Services including wireless networks, for some computers connecting to the Internet, it may be desirable for the computer to have a unique IP address while connected to a network of non-unique IP addresses. For example, a fixed wireless network may provide a user a data connection to then connect to the internet service provider of the user's choice. Presently such a connection can be implemented by first connecting the user using DHCP with a private IP address and then making a virtual private

network (VPN) connection to a Network Access Server (NAS) to connect to the service provider which assigns a second public IP address within the VPN tunnel. Packets outbound from the user device are encapsulated with their private source address in the exterior IP header and their public source address in the interior IP header. The exterior destination address of the packet is the NAS and the interior destination address is the actual destination of the packet. Packets inbound to the user device are encapsulated at the NAS to have their exterior destination address set to the private user device address and their interior destination address set to the public user device IP address. One of the problems of such a technique is the additional overhead incurred in encapsulating and decapsulating the packets which reduces the effective usable bandwidth.

Referring now to Fig. 1, a network 100 includes a customer network 2 connected to a private network 4 which is connected to a public network 6. The customer network 2 is connected to the private network 4 using a device 20, here a router, that operates in a manner as described further hereinafter. The private network 4 is connected to the public network 6 using a device 30, here a border router, that operates in a manner as described further hereinafter. Typically, the public network 6 is used for passing a datagram (not shown) whose destination is specified by a globally unique Internet Protocol (IP) address. The public network 6 is connected to the device 30 which performs network address translation of said globally unique IP address to a non-globally unique IP address in the private network 4. The second device 20 is connected to the private network 4 for routing said datagram to a user device connected to the customer network 2 wherein

said user device includes the destination specified by said non-globally unique IP address. The second device 20 performs network address translation to said non-globally unique IP address to the corresponding globally unique IP address. With such an arrangement, a technique is provided wherein a public network can be extended across a private network to facilitate orderly topology-based routing to the computers via the private address network. It should soon be appreciated that such a technique provides an ability to use and transport data traffic across private address infrastructure transparent to devices in surrounding public networks.

Referring now to Fig. 1A, the network 100 is shown to include a user device 10 here having assigned a global unique IP address 24.128.225.93. The user device 10 could be a stand-alone workstation or any communication device or a stub router with many private workstations connected to it. The user device 10 is connected to a private network router 20. The private network router 20 is capable of performing network address translation to translate between a global unique IP address and a non-global unique IP address. The private network router 20 is connected to a second private network router 30. The private network router 30 is capable of performing network address to translate between a non-global unique IP address and a global unique IP address. It should be appreciated that although the connection from private network router 20 to private network router 30 is shown as a direct connection, the connection can be accomplished using any data network connectivity including multiple routers as well as fiber and radio transmission connectivity. The private network router 30 is connected to a service provider 40 which in turn is

connected to the Internet 50. As contemplated, the private network is using non-global unique IP addresses in a first network and the user device 10 and the service provider 40 is using a global unique IP address in a second network.

When the user device 10 initiates an outbound session, it transmits a datagram 10', for example, with the source IP address of 24.128.225.93 (i.e., a global unique IP address) and destination IP address of 216.41.29.6 (e.g., here an IP address assigned to another organization's network). The private network router 20 maps the source IP address to one of the private network's available non-globally unique IP addresses (e.g., 10.0.0.93) before forwarding the packet to the private network. This is shown by datagram 20'. Following networking protocol within the private network, the datagram 20' arrives at private network router 30 as datagram 30' where the private network router 30 maps the source IP address to one of the service provider network's available globally unique IP addresses (e.g., 24.128.225.93), the IP address that was previously assigned to the user device 10, before forwarding the packet to the service provider 40. This is shown by datagram 40'. The service provider 40 then forwards the packet as necessary to the Internet 50 so the packet can be delivered to its ultimate destination.

If a reply should come back (i.e., inbound) it would contain a source IP address of 216.41.29.6 and a destination IP address of 24.128.225.93. This is shown by datagram 40". The service provider 40 would forward the datagram 40" to the private network router 30 and the private network router 30 would then map the destination IP address to 10.0.0.93 and forward the datagram 30" to the private

network router 20 as datagram 20". The private network router 20 would then map the destination IP address to 24.128.225.93 and forward the datagram to user device 10 so that the original session (and thus user) can receive their reply. This is shown by datagram 10". The above dataflow illustrates that basic address translation functionality according to the present invention. Thus, by performing network address translation at the first private network router 20 and again, in a corresponding manner, at the second private network router 30, a public network can be routed across a private network. Such a technique eliminates a need for inspection and possible modification of IP datagram payload when translating addresses in the IP datagram header (sometimes referred to as application level gateways). Furthermore, this technique allows arbitrary end-to-end IP datagram encryption and authentication arrangements to inter-operate between public networks separated by a shared private network.

The present invention may be implemented using hardware, software or a combination thereof and may be implemented in a computer system (for example a "router") or other processing system included within a private network's access server. In fact, in one embodiment, the invention is directed toward a computer system capable of carrying out the functionality described herein. An example of a computer system 200 is shown in FIG. 2. The computer system 200 includes one or more processors, such as processor 204. The processor 204 is connected to a communication bus 206. Various software embodiments are described in terms of this example computer system. After reading this description, it will become apparent to a

person skilled in the relevant art how to implement the invention using other computer systems and/or computer architectures.

Computer system 200 also includes a main memory 208, preferably random access memory (RAM), and can also include a secondary memory 210. The secondary memory 210 can include, for example, a hard disk drive 212 and/or a removable storage drive 214, representing a floppy disk drive, a magnetic tape drive, an optical disk drive, etc. The removable storage drive 214 reads from and/or writes to the hard disk drive 212 in a well known manner. As will be appreciated, the removable storage unit 614 includes a computer usable storage medium having stored therein computer software and/or data.

In alternative embodiments, secondary memory 210 may include other similar means for allowing computer programs or other instructions to be loaded into computer system 200. Examples of such can include flash memory with a memory interface 216, a program cartridge and cartridge interface (such as that found in video game devices), a removable memory chip (such as an EPROM, or PROM) and associated socket, which allow software and data to be transferred to computer system 200. Computer system 200 can also include a communications interface 218. Communications interface 218 allows software and data to be transferred between computer system 600 and external devices. Examples of communications interface 218 can include a modem, a network interface (such as an Ethernet card), a communications port, a PCMCIA slot and card, etc. Software and data transferred via communications interface 218 are in the form of signals which can be electronic, electromagnetic, optical or other signals capable of being received by communications interface 218. These

signals are provided to communications interface 218 via a communications path (i.e., channel). This channel (not shown) carries signals and can be implemented using wire or cable, fiber optics, a phone line, a cellular phone link, an RF link and other communications channels. In this description, the terms "computer program medium" and "computer usable medium" are used to generally refer to media such as removable storage drive 214, a hard disk installed in hard disk drive 212, and the like (e.g., flash memory). These computer program products are means for providing software to computer system 200. Computer programs (also called computer control logic) are stored in main memory 208 and/or secondary memory 210. Computer programs can also be received via communications interface 218. Such computer programs, when executed, enable the computer system 200 to perform the features of the present invention as discussed herein. In particular, the computer programs, when executed, enable the processor 204 to perform the features of the present invention. Accordingly, such computer programs represent controllers of the computer system 200.

In an embodiment where the invention is implemented using software, the software may be stored in a computer program product and loaded into computer system 200 using removable storage drive 214, hard drive 212, communications interface 218 and the like (e.g., flash memory). The control logic (software), when executed by the processor 204, causes the processor 204 to perform the functions of the invention as described herein.

In another embodiment, the invention is implemented primarily in hardware using, for example, hardware components such as application specific integrated circuits (ASICs). Implementation of the

hardware state machine so as to perform the functions described herein will be apparent to persons skilled in the relevant art(s). In yet another embodiment, the invention is implemented using a combination of both hardware and software.

Referring now to Figs. 3 and 3A, a data network 100 using wireless LAN technology shall be described showing the details of how a customer or user device 10 obtains a public IP address and how a radio unit RU 20 (private network router 20) and border router (BR) 30 (private network router 30) learn the corresponding address translation entries for the associated private address using the contemplated technique.

During the initial dynamic host control protocol (DHCP) handshake the user's PC or customer device 10 obtains a private IP address for use during the registration process since which ISP service provider the user will use is not yet known. The RU 20 is statically provisioned with an IP address (10.0.0.1/29 in the present example) and the address of the DHCP server 32. The DHCP server 32 responds by offering the device 10 a private IP address for temporary use while the (customer) user device 10 establishes service. The customer device 10 next contacts the Registration Server 34 which proxy registers with a chosen ISP to establish the service. The RU 20 will allow all traffic inbound to the user device 10, using its temporary private address, to be routed to its home local area network (HLAN) since no network address translation yet exists. The ARP binding with the customer device 10's physical address and private IP address is learned by the RU 20 during the DHCP exchange. When the Registration Server 34 completes the registration, it uses an SNMP SET directive to inform the

Service and Policy (S&P) Server 32, which in turn triggers the BR 30 to choose a public IP address from the selected ISP address pool. The BR 30 enters the address translation entry into its Symmetric Address Translation (SAT) table 30a. Up to this point the process is the same as for the ordinary NAT registration. Now however, the BR 30 uses an SNMP SET command to inform the S&P Server 32 of the completed public/private IP address binding. The S&P Server 32 in turn uses SNMP SET command to configure its own database and the RU 20 with the same public/private SAT entry. The final step in the configuration is to signal the user to reboot the customer device 10. This is done so that the next interaction with the DHCP 32 will offer the public address assigned from the now-registered ISP address pool as shown in Fig. 4.

Once the user has established service, other devices, such as device 12, attached to the RU 20 can obtain a public IP address in a similar fashion as shown in Fig. 5. The primary difference in the process is that, once the DHCP server 32 receives the DISCOVER message and recognizes a registered customer, via the identity from the RU 20, it does not reply with a temporary private address. Instead, the S&P Server 32 informs the BR 30 of the private address, here 10.0.0.3 in the example, of the device 12 and its service policy. The BR 30 then chooses a valid public address from the corresponding ISP address pool and binds the public/private association into its SAT table 30a. Next the BR 30 informs the S&P server 32 of the public/private IP binding which is used to configure its internal DHCP server (not shown). The S&P server 32 informs the RU 20 in turn of the public/private address binding. When this is done the DHCP server 32 returns the DHCP

OFFER message with the public address to the customer device 12, which then can begin communicating once the DHCP REQUEST/ACK handshaking is completed, as shown in Fig. 4.

It should be appreciated that the technique described by which the BR and RU some to know the public/private address bindings can be accomplished in a variety of similar ways yielding the same results. For example, the BR and RU could passively learn the address bindings by inspecting the DHCP exchanges between the user device and the DHCP server.

The contemplated technique, referred to herein as Symmetric Address Translation (SAT), relies on the coordinated, symmetric use of the IP address translation at the RU 20 and BR 30. In the unlikely event that synchronization of SAT tables is lost or corrupted for any reason, the user sessions will time out and be lost. This will require the user devices 10 DHCP process to interact again with the internal DHCP server of the S&P Server 32. The S&P server 32, even if it has a valid public/private IP binding for the physical address of the requesting device, must again interact with the BR 30 via SNMP to confirm the binding before offering the public IP address to the user device 10. If for some reason the BR 30 no longer has the same private/public address alias binding, the S&P Server 32 will update its internal DHCP server configuration and the RU's 20 SAT table 20a to the new binding before offering the new public address to the device. In this way, SAT table synchronization can be restored.

One attractive feature of the inventive technique will be the ability to leverage the broadcast nature of the air interface from the Base Stations 22 to economically 'push' content to customer device 10

on the Home LANs (HLANs) from servers within the network infrastructure (e.g., the DSN). This is accomplished by using net-10 IP broadcast to the Base Stations 22. The Base Stations 22 will in turn use the Air Interface broadcast channel to deliver the traffic to the RU 20. The RU 20 will translate the net-10 broadcast to the global broadcast address and place it on the HLAN 14 with the broadcast physical address so that all devices physically on the HLAN 14 can see the traffic. IP multicasting can be used to selectively deliver content to customer device 10, 12 with increased flexibility. The latter provides the ability to broadcast or multicast to a group of unique address devices based on a non-unique broadcast or multicast address.

It should be appreciated that one difference between typical NAT and SAT is the customer devices 10 forming the HLAN 14 could have disjoint public addresses as opposed to belonging to a private IP address subnet. This is not as bad as it first appears since none of the traffic between devices attached to the RU 20 would need to use the air interface. The implication for the RU 20 is that it would have to assume some lightweight router functionality as follows. Every device on the RU 20 HLAN 14 would use the RU 20 as the gateway. The RU 20 would monitor the DHCP messages to build ARP tables for the attached devices. If device 10 on the HLAN 14 needed to communicate with device 12 then device 10 would ARP for the physical address of device 12 if it determined that device 12 was on the same subnet. Device 12 would reply to device 10 providing its physical address and communication would proceed as normal. If device 12 had an IP address that was on a different logical subnet, then device 10 would attempt to use RU 20 as the gateway to reach device

12. For instance, this might happen if device 10 was registered with a first internet service provider (ISP) ISP1 and device 12 was registered with a second ISP, ISP2 (assuming the two ISPs provided disjoint public address pools). The RU 20 on receiving the traffic from device 10 would examine its routing table and discover that device 12 was on the same physical interface and, using its ARP table, would forward the traffic on to device 12 after changing the physical destination address to correspond to device 12. The RU 20 builds up the ARP table by examining the DHCP messages between its attached clients and the DHCP server. On the other hand, if the pool(s) of addresses provided by the ISP were contiguous or subnetted so that any public address belonging to the same IP provider would appear to be on the same subnet. In that case device 10 would communication with device 12 without using the RU 20 as the intermediary (assuming they were registered with the same ISP). Also, any attempt to reach customer devices not on the same physical HLAN could be blocked by the RU 20 except in cases where a valid ARP entry existed in the RU 20's ARP table. Conceivably, public addresses could be allocated in subnet groups assigned to a particular RU. This would work by allocating a small subnet of public addresses (e.g., /29) from a common pool or set of pools of public addresses. When the customer registers their PC (user device) with a given ISP, the subnet would be allocated to the RU and any device attached to that RU. The customer PC (user device) would receive one of these public addresses and a corresponding private address. The BR 30 in this case would enter a subnet block of network address entries into its table to prevent future requests from devices on other RUs from binding to the same public addresses. Any

device on the same HLAN contacting the DHCP server thereafter would receive one of the public addresses in the same subnet and the RU would update its SAT table according to the number of active devices. The advantage gained by this technique would be that the public addresses could be associated with a particular RU (e.g., for QoS routing within the private network infrastructure) so that SAT of outbound traffic from the RU would not be needed. However, a major disadvantage would be that ISP public addresses would have to be reserved on a per-RU basis whether or not the customer ever used them. For example, a Class-B public address block could support only about 213 (8k) RU's each with /29 subnets as opposed to 2^{16} (64k) hosts in the disjoint case (i.e. potentially many more RU's if on the average each RU had only one or two attached devices on the HLAN).

The transparent nature of SAT comes from the coordinated symmetric use of the address translation at the RU 20 and BR 30. For internal destinations inside the private network infrastructure (e.g., the DSN Registration Server 34) the BR 30 might not be included in the path and hence only a single SAT interface at the RU 20 would be traversed. The implication for the network is that this internal traffic will require special handling. Consider the case of the customer device 10 contacting the Registration Server 34 to set up their service policy. There are two scenarios depending on whether or not the option to SAT outbound traffic at the RU 20 is used. For clarity, Unidirectional SAT will refer to the scenario where only inbound traffic is address translated. Bidirectional SAT will refer to the scenario where both inbound and outbound traffic is translated.

In the unidirectional SAT scenario, traffic from customer devices 10 can reach any allowed internal destination including the Registration Server 34. The packets however will arrive with their public Source Address (SA). The problem then is how to route the response traffic back to the customer device 10. One method is to have the internal router 24 that the Registration Server 34 is attached to, provisioned to route any public destination addresses to the exterior interface of the BR 30. The BR 30 would recognize the public address as a reachable destination within the FWS private network, address translate it to the corresponding private address which then would be routed in the normal fashion to the correct RU 20. The RU 20 would address translate it back to the public address and deliver it to the customer device 10. All the advantages of SAT would apply.

Alternatively, the RU 20 could be configured to only address translate outbound traffic when the destination was a private address since these would all be FWS internal destinations. The packets would then arrive at the Registration Server 34 with their private SA so that responses would be routed normally within the net-10 network. The RU 20 receiving traffic from the Registration Server 34 would network address translate the traffic as usual to the correct public address and deliver the packets to the customer device 10. The disadvantage here is that there would be no simple way to support protocols that required NAT editing between the customer device 10 and internal servers. But for example, HTTP sessions could operate normally.

In the bidirectional SAT scenario, the RU 20 would normally address translate all outbound traffic. The packets would then arrive at the Registration Server 34 with their private SA so that responses

would be routed normally within the net-10 network. The RU 20 receiving traffic from the Registration Server 34 would network address translate the traffic as usual to the correct public address and deliver the packets to the customer device 10. Again, the only disadvantage here is that there would be no simple way to support protocols that required NAT editing between the customer device 10 and internal servers. This might not be a serious problem, for example HTTP sessions do not require NAT editing and could operating normally.

Alternatively, the RU 20 could be configured to not address translate outbound traffic when the destination was a private address since these would all be FWS internal destinations. Traffic from customer devices 10 can reach any allowed internal destination including the Registration Server 34. The packets however will arrive with their public SA. The problem then is how to route the response traffic back to the customer device 10. One method is to have the internal router 24 that the Registration Server 34 is attached to, provisioned to route any public destination addresses to the exterior interface of the BR 30. The BR 30 would recognize the public address as a reachable destination within the FWS network, address translate it to the corresponding private address which then would be routed in the normal fashion to the correct RU 20. The RU 20 would address translate it back to the public address and deliver it to the customer device 10. All the advantages of SAT would apply.

It should now be appreciated that depending upon the type of service customers desire, the contemplated technique provides for assigning a non-globally unique IP address when connectivity to only a

non-unique address network is desired and a unique address when connectivity to networks requiring unique addressing is desired. For example, if the customer only desires Web (HTTP) access and a HTTP Proxy Server is located in the private network, then only a non-globally unique IP address is needed. If the customer wishes to connect to an ISP having a network using globally unique address, then a globally unique address can also be assigned.

Referring now to Fig. 6, a network 200 includes a private network 102 connected to a public network 104 which is connected to a private network 6 using the advantages of SAT. The private networks 102, 104 use non-globally unique addresses, whereas the public network 104 uses globally unique addresses. With such an arrangement, geographically separated private networks can be connected by using the public network for communicating among the private network users within the private network. The private network 102 is connected to the public network 104 using a device 120, here a router, that operates in a manner as described further hereinafter. The public network 104 is connected to the private network 106 using a device 130, here a router, that operates in a manner as described further hereinafter. The private network 102 is connected to the device 120 which performs network address translation of said non-globally unique IP address to a globally unique IP address in the public network 104. The device 120 is connected to the public network 104 for routing said datagram from a user device connected to the private network 102 wherein said user device includes the destination specified by said non-globally unique IP address. The device 120 performs network address translation to said non-globally unique IP address to a globally unique

IP address. When the datagram arrives at the device 130, the device 130, using the technique of symmetric address translation, performs network address translation to said globally unique IP address to a corresponding non-globally unique IP address. With such an arrangement, a private network can be extended across a public network to another portion of the private network.

The network 200 is shown to include a user device 110 here having assigned a non-global unique IP address 10.0.0.93. The user device 110 could be a stand-alone workstation or any communication device or a stub router with many private workstations connected to it. The user device 110 is connected via the private network 102 to a private network router 120. The private network router 120 is capable of performing network address translation to translate between a non-global unique IP address and a global unique IP address. The private network router 120 is connected across public network 104 to a second private network router 130. The private network router 130 is capable of performing network address to translate between the global unique IP address and a non-global unique IP address. It should be appreciated that although the connection from private network router 120 to private network router 130 is shown as a direct connection, the connection can be accomplished using any data network connectivity including multiple routers as well as fiber and radio transmission connectivity. The private network router 130 is connected to another portion of the private network 102, here private network 106. A user device 140 is connected to the private network 106. As contemplated, the private network 102 is using non-global unique IP addresses in a subnet configuration to be in the same network as the private network 106.

Thus, user device 110 can communicate with user device 140 as though they were on the same network. The private network router 120 and the private network router 130 are configured with table information to match up respective non-global unique IP addresses. As more users are added to the private network, the respective SAT tables would be passed back and forth (handshake) between the private network router 120 and the private network router 130. Using symmetric address translation (SAT) the devices (i.e. user device 110) on the private network 102 can communicate with the devices (i.e. user device 140) on private network 106 as though they were on a contiguous single network. It should be appreciated that a third private network (not shown) could be added and connected to the private networks 102, 104 through the public network 104 in a similar manner.

It should now be appreciated the present invention includes a first device for receiving a datagram from a public network whose destination is specified by a globally unique Internet Protocol (IP) address and for performing network address translation of said globally unique IP address to a non-globally unique IP address in a private network; and a second device for routing said datagram to a user device connected to the second device wherein said user device includes the destination specified by said non-globally unique IP address and for performing basic network address translation to said non-globally unique IP address to said corresponding globally unique IP address. With such an arrangement, a system is provided wherein a public network can be extended across a private network address to facilitate the number of computers that can be connected to the Internet and to facilitate orderly topology-based routing to the computers via the

private address network. Furthermore, the second device is adapted to initially assign an IP address of the private network to a user device and is adapted to handshake with a registration server to proxy register with an internet service provider to select an IP address of the public network and replace the IP address of the user device with the IP address of the public network. The system further includes a local network connected to the user device, the user device being assigned a globally unique IP addresses, the local network being assigned a set of non-unique IP addresses, the user device adapted for performing network address translation from the local network to the corresponding public network. With such an arrangement, existing local private networks can connect to a public network across a common carrier private network.

All publications and references cited herein are expressly incorporated herein by reference in their entirety.

Having described the preferred embodiments of the invention, it will now become apparent to one of ordinary skill in the art that other embodiments incorporating their concepts may be used. It is felt therefore that these embodiments should not be limited to disclosed embodiments but rather should be limited only by the spirit and scope of the appended claims.

Claims:

1. A system comprising:

a first device for performing network address translation from a first network to a second network; and

a second device for performing network address translation from the second network to the corresponding first network.

2. The system as recited in claim 1 wherein the first device comprises:

a processor for receiving/transmitting a datagram from said first network having a destination address with a unique IP address in the first network and mapping said first network unique IP address to a unique IP address in the second network; and

wherein the second device comprises:

a processor for mapping said second network unique IP address to said first network unique IP address.

3. The system as recited in claim 1 wherein:

the second device comprises a processor for receiving from a user device having a unique IP address in the first network a datagram having a source address with a non-globally unique IP address and having a destination address with a globally unique IP address and mapping said non-globally unique IP address of the source address to the unique IP address of the first network and for routing said datagram to the first network.

4. The system as recited in claim 1 wherein said first network is a public network and said second network is a private network.

5. The system as recited in claim 1 wherein said first network is assigned a set of globally unique IP addresses and said second network is assigned a set of non-globally unique IP addresses.

6. The system as recited in claim 1 further comprising:

a local network connected to the second device, the local network having at least one of a plurality of user devices connected via the local network, the local network being assigned a set of unique IP addresses from the first network.

7. The system as recited in claim 6 wherein the second device, with a connection to one of the plurality of computer workstations initially having an IP address of the second network, is adapted to handshake with a registration server to proxy register with an internet service provider to select an IP address of the first network and provide the IP address of the first network to said one of the plurality of workstations.

8. The system as recited in claim 6 wherein the second device is adapted to initially handshake with an address server to assign an IP address of the second network to a user device and is adapted to handshake with a registration server to proxy register with an internet service provider to select an IP address of the first network and replace the IP address of the user device with the IP address of the first network.

9. The system as recited in claim 1 further comprising:

a user device connected to the second device, the user device being assigned a unique IP addresses from the first network, the user device connected to a local network, the local network being assigned a set of non-unique IP addresses, the user device adapted for performing network address translation from the local network to the corresponding first network.

10. A system comprising:

a first device for receiving a datagram from a public network whose destination is specified by a globally unique Internet Protocol (IP) address and for mapping said globally unique IP address to a non-globally unique IP address in a private network; and

a second device for routing said datagram to a user device connected to the second device wherein said user device includes the destination specified by said non-globally unique IP address and for mapping said non-globally unique IP address to said corresponding globally unique IP address.

11. The system as recited in claim 10 wherein each mapping device comprises means for performing basic network address translation.

12. The system as recited in claim 10 comprising a local network connected to the user device, the user device being assigned a globally unique IP addresses, the user device connected to a local network, the local network being assigned a set of non-unique IP addresses, the user device adapted for performing network address translation from the local network to the corresponding public network.

13. The system as recited in claim 10 wherein the second device, with a connection to the user device initially having an IP address of the private network, is adapted to handshake with a registration server to proxy register with an internet service provider to select an IP address of the public network and provide the IP address of the public network to said user device.

14. The system as recited in claim 10 wherein the second device is adapted to initially handshake with an address server to assign an IP address of the private network to a user device and is adapted to handshake with a registration server to proxy register with an internet service provider to select an IP address of the public network and

replace the IP address of the user device with the IP address of the public network.

15. The system as recited in claim 10 comprising computer readable program code comprising:

a first computer readable program code for causing a computer to receive the datagram from the Internet whose destination is specified by the globally unique Internet Protocol (IP) address and for causing the computer to map said globally unique IP address to the non-globally unique IP address; and

a second computer readable program code for causing a computer to receive the datagram whose destination is specified by the non-globally unique Internet Protocol (IP) address and for causing the computer to map said globally non-unique IP address to the corresponding globally unique IP address.

16. A system for performing network address translation comprising:

a first device for connecting to a public network, said public network including a globally unique Internet Protocol address, said first device capable of performing network address translation from the globally unique Internet Protocol address to a non-globally unique Internet Protocol address; and

a second device for connecting a user device to the public network, said second device capable of performing network address translation from the non-globally unique Internet Protocol address to the corresponding globally unique Internet Protocol address.

17. The system as recited in claim 16 wherein the second device, with a connection to the user device initially having an IP address of

the private network, is adapted to handshake with a registration server to proxy register with an internet service provider to select an IP address of the public network and provide the IP address of the public network to said user device.

18. The system as recited in claim 16 wherein the second device is adapted to provide an IP address of the private network to a user device and is adapted to handshake with a registration server to proxy register with an internet service provider to select an Internet Protocol address of the public network and replace the Internet Protocol address of the user device with the Internet Protocol address of the public network.

19. The system as recited in claim 16 comprising a local network connected to the user device, the user device being assigned a globally unique Internet Protocol addresses, the user device connected to a local network, the local network being assigned a set of non-unique Internet Protocol addresses, the user device adapted for performing network address translation from the local network to the corresponding public network.

20. The system as recited in claim 16 wherein the first device and second device is adapted to eliminate a need for inspection and possible modification of IP datagram data content when translating addresses in the IP datagram header.

21. The system as recited in claim 16 wherein the first device and second device is adapted to allow arbitrary end-to-end IP datagram encryption and authentication arrangements to inter-operate between public networks separated by a shared private network.

22. The system as recited in claim 16 wherein the second device is adapted to use non-globally unique IP addresses to collectively deliver content to a plurality of user devices.

23. The system as recited in claim 16 comprising a content server adapted to use non-globally unique IP addresses to collectively deliver content to a plurality of user devices.

24. The system as recited in claim 16 wherein the second device is adapted to selectively assigning a non-globally unique IP address when connectivity to only a non-unique address network is required and a globally unique IP address when connectivity to networks requiring unique addressing is required.

25. A system for performing network address translation comprising:

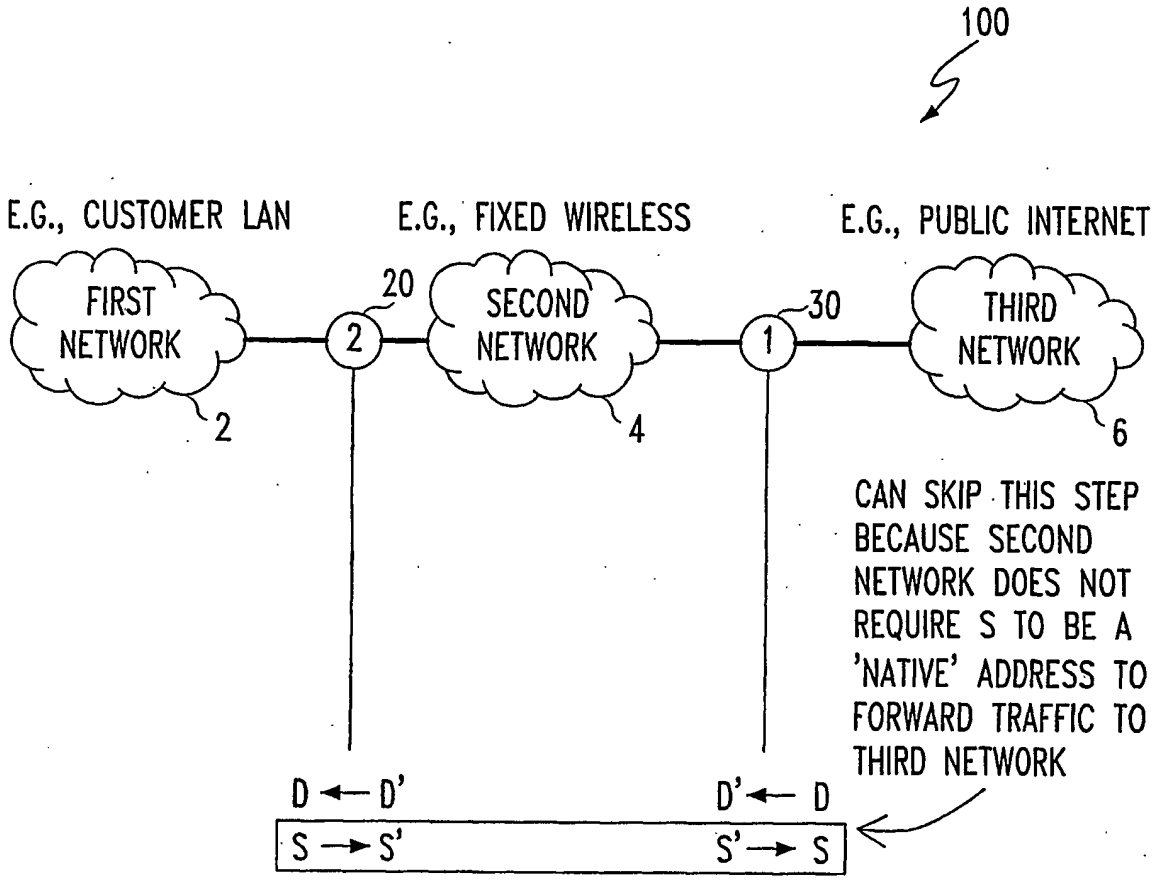
a first device for connecting a first private network to a public network, said public network including a globally unique Internet Protocol address, said first device capable of performing network address translation from a non-globally unique Internet Protocol address of the first network to a globally unique Internet Protocol address; and

a second device for connecting a second private network using non-globally unique Internet Protocol addresses to the public network, said second device capable of performing corresponding network address translation from a non-globally unique Internet Protocol address of the second network to a globally unique Internet Protocol address, the first device and the second device communicating with each other to provide a contiguous single network between the first private network and the second private network.

26. A computer program product comprising a computer usable medium having computer readable program code embodied in said medium for causing an application program to execute on a computer that performs network address translation, said computer readable program code comprising:

a first computer readable program code for causing a computer to receive a datagram from the Internet whose destination is specified by a globally unique Internet Protocol (IP) address and for causing the computer to map said globally unique IP address to a non-globally unique IP address; and

a second computer readable program code for causing a computer to receive a datagram whose destination is specified by a non-globally unique Internet Protocol (IP) address and for causing the computer to map said globally non-unique IP address to the corresponding globally unique IP address.



KEY:

D= DESTINATION ADDRESS IN IP DATAGRAM
S= SOURCE ADDRESS IN IP DATAGRAM
[D,S]= GLOBALLY UNIQUE IP ADDRESSES
[D',S']= NON GLOBALLY UNIQUE IP ADDRESSES
▭ = OPTIONAL STEP

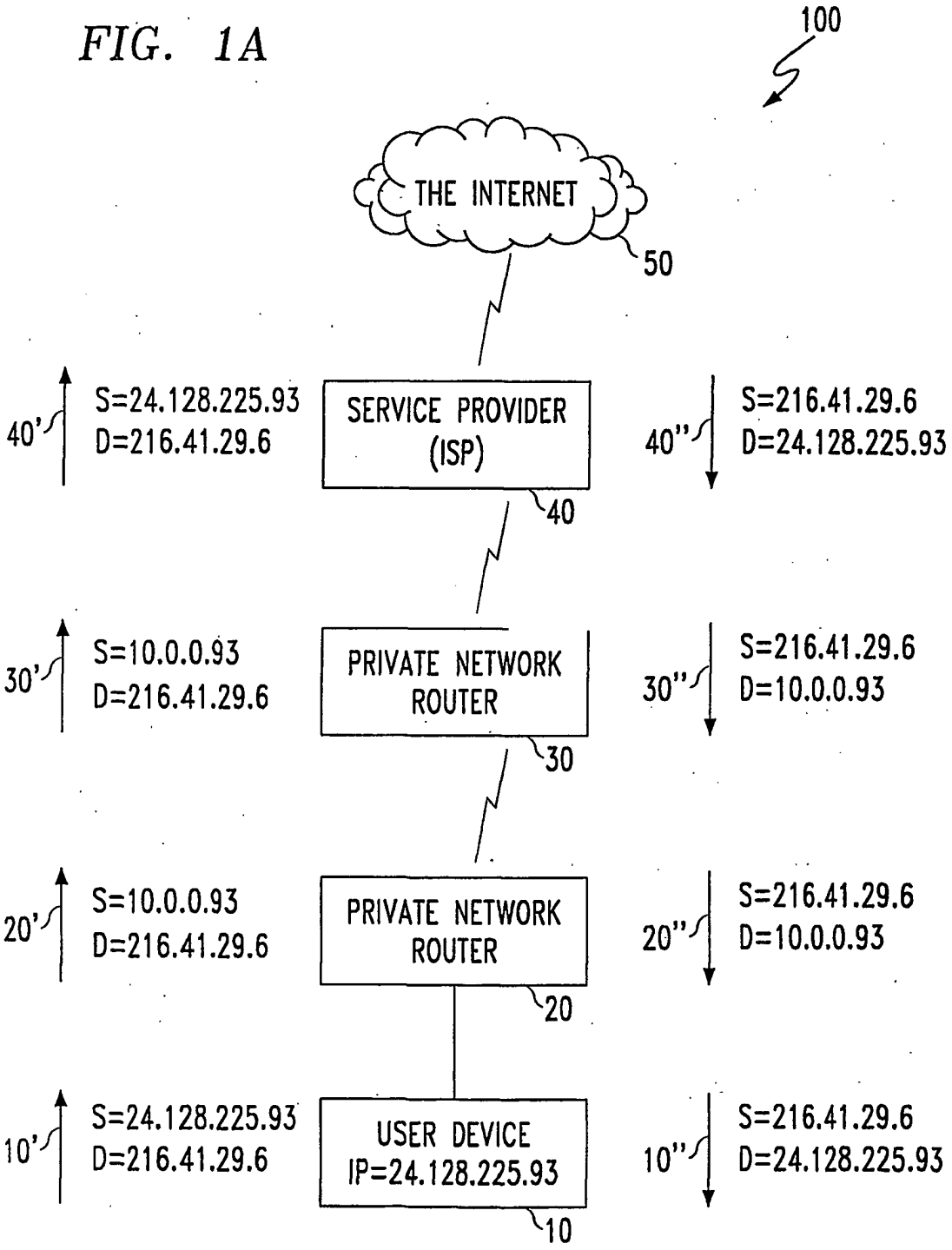
ASSUMPTIONS:

- FIRST NETWORK AND THIRD NETWORK USE GLOBALLY UNIQUE ADDRESS

- SECOND NETWORK USES NON GLOBALLY UNIQUE ADDRESSES

FIG. 1

FIG. 1A


100
THE INTERNET
50
SERVICE PROVIDER (ISP)
40
40'
S=24.128.225.93
D=216.41.29.6
40"
S=216.41.29.6
D=24.128.225.93
PRIVATE NETWORK ROUTER
30
30'
S=10.0.0.93
D=216.41.29.6
30"
S=216.41.29.6
D=10.0.0.93
PRIVATE NETWORK ROUTER
20
20'
S=10.0.0.93
D=216.41.29.6
20"
S=216.41.29.6
D=10.0.0.93
USER DEVICE
IP=24.128.225.93
10
10'
S=24.128.225.93
D=216.41.29.6
10"
S=216.41.29.6
D=24.128.225.93

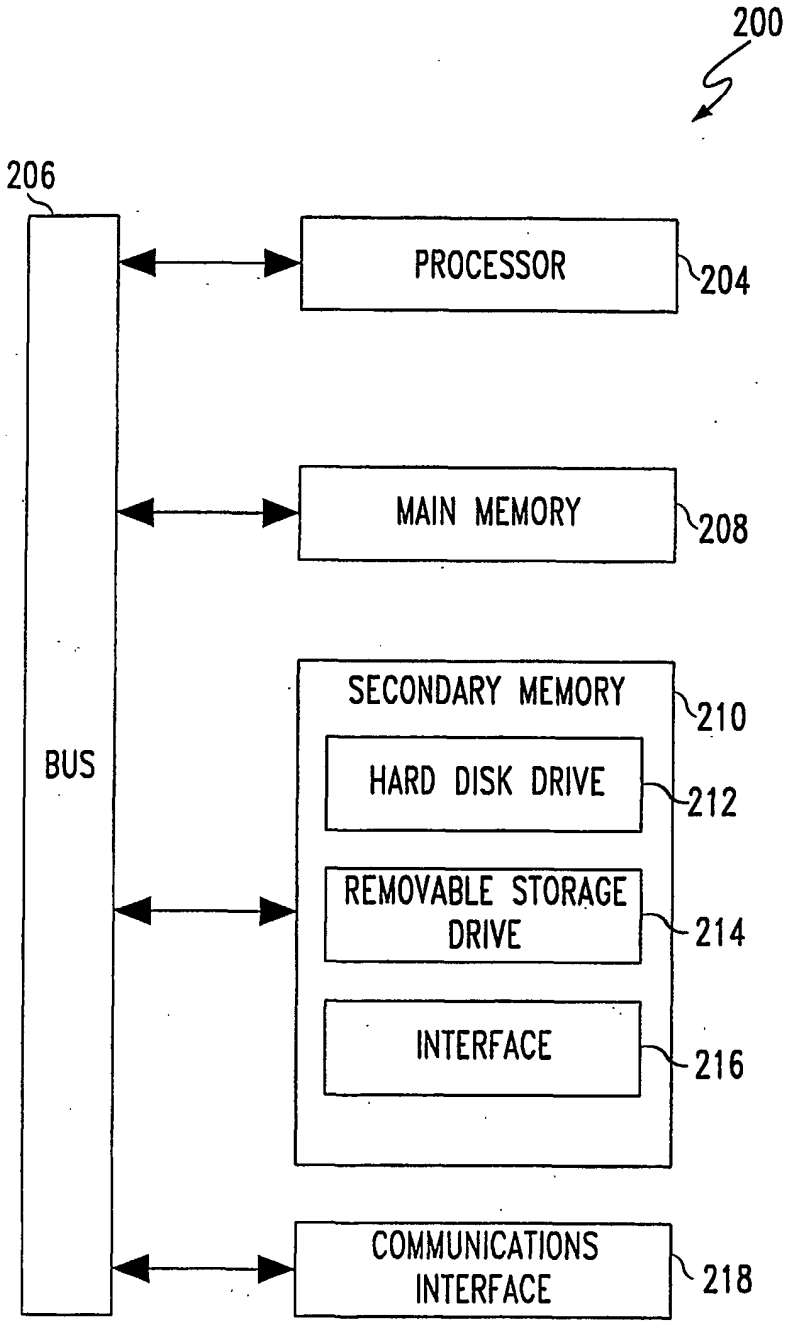

200
206
PROCESSOR
204
MAIN MEMORY
208
SECONDARY MEMORY
210
HARD DISK DRIVE
212
REMOVABLE STORAGE DRIVE
214
INTERFACE
216
BUS
COMMUNICATIONS INTERFACE
218

FIG. 2

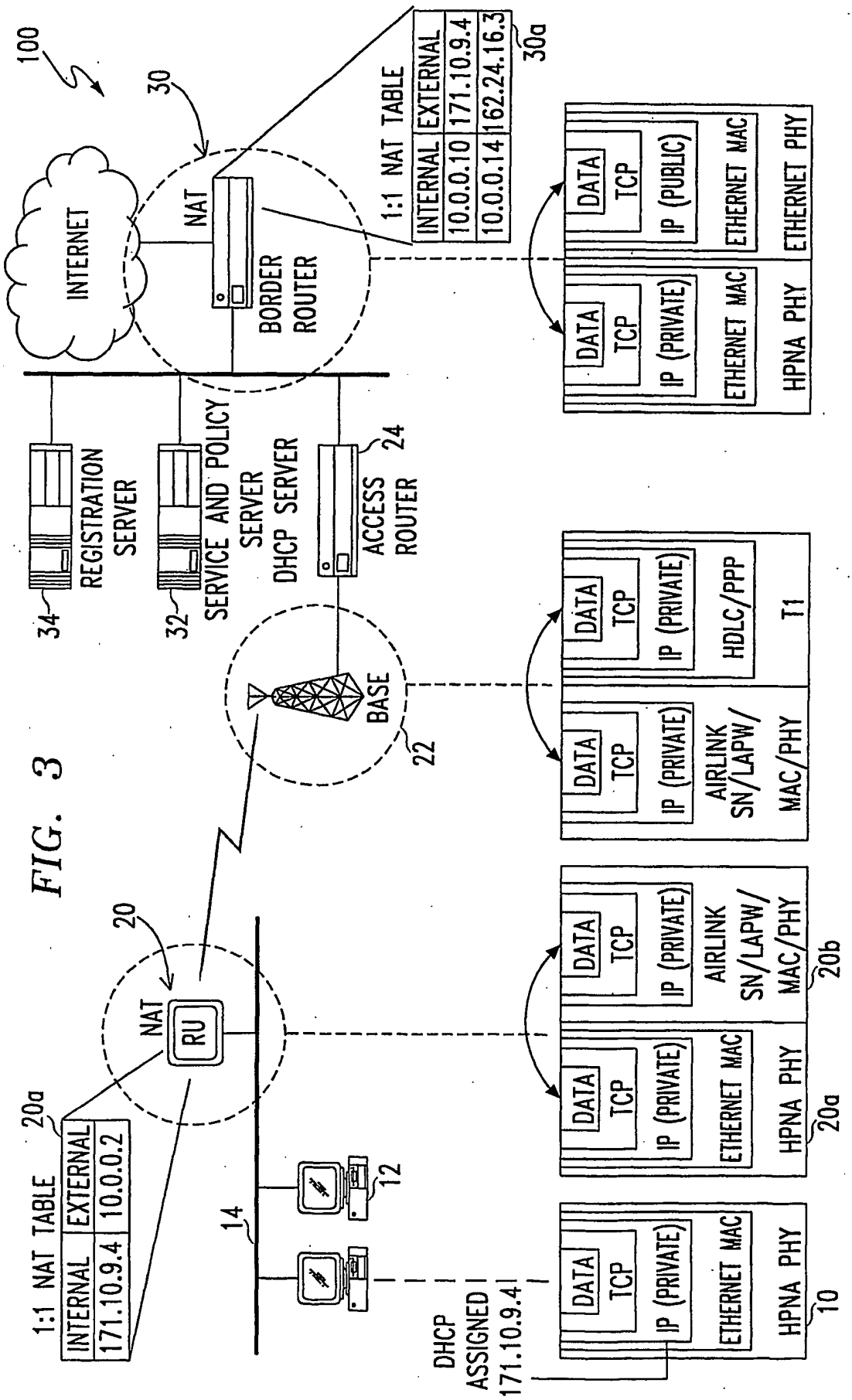

100
30
INTERNET
NAT
BORDER ROUTER
1:1 NAT TABLE
INTERNAL EXTERNAL
10.0.0.10 171.10.9.4
10.0.0.14 162.24.16.3
30a
REGISTRATION SERVER
34
SERVICE AND POLICY SERVER
32
DHCP SERVER
ACCESS ROUTER
24
BASE
22
20
NAT
RU
1:1 NAT TABLE
INTERNAL EXTERNAL
171.10.9.4 10.0.0.2
20a
14
12
DHCP ASSIGNED
171.10.9.4
DATA
TCP
IP (PRIVATE)
ETHERNET MAC
HPNA PHY
10
AIRLINK SN/LAPW/ MAC/PHY
20a
20b
HDLC/PPP
T1
IP (PUBLIC)
ETHERNET PHY

FIG. 3

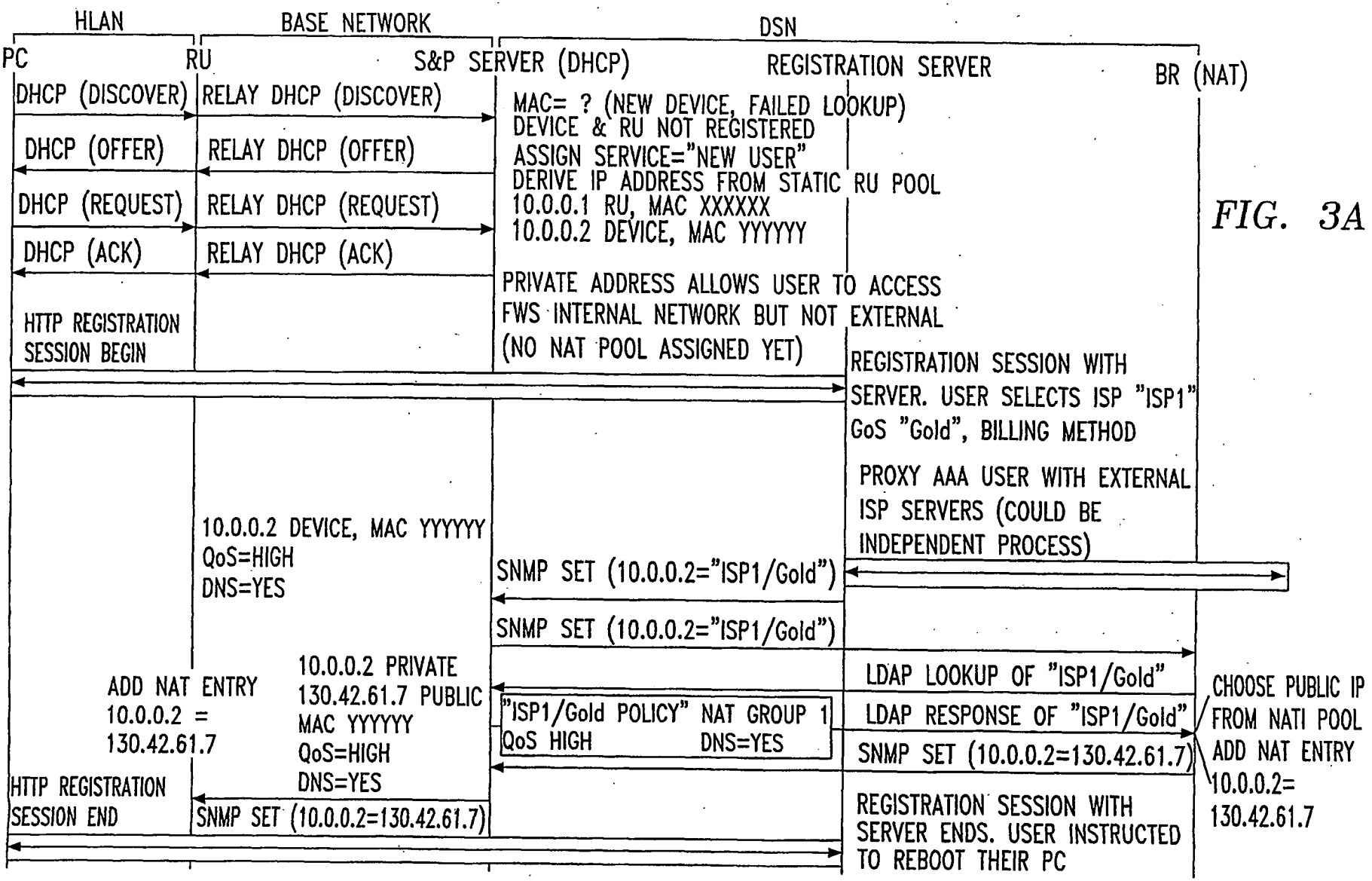

HLAN
BASE NETWORK
DSN
PC
RU
S&P SERVER (DHCP)
REGISTRATION SERVER
BR (NAT)
DHCP (DISCOVER)
RELAY DHCP (DISCOVER)
MAC= ? (NEW DEVICE, FAILED LOOKUP)
DEVICE & RU NOT REGISTERED
ASSIGN SERVICE="NEW USER"
DERIVE IP ADDRESS FROM STATIC RU POOL
10.0.0.1 RU, MAC XXXXXX
10.0.0.2 DEVICE, MAC YYYYYY
DHCP (OFFER)
RELAY DHCP (OFFER)
DHCP (REQUEST)
RELAY DHCP (REQUEST)
DHCP (ACK)
RELAY DHCP (ACK)
PRIVATE ADDRESS ALLOWS USER TO ACCESS
FWS INTERNAL NETWORK BUT NOT EXTERNAL
(NO NAT POOL ASSIGNED YET)
HTTP REGISTRATION
SESSION BEGIN
REGISTRATION SESSION WITH
SERVER. USER SELECTS ISP "ISP1"
GoS "Gold", BILLING METHOD
PROXY AAA USER WITH EXTERNAL
ISP SERVERS (COULD BE
INDEPENDENT PROCESS)
10.0.0.2 DEVICE, MAC YYYYYY
QoS=HIGH
DNS=YES
SNMP SET (10.0.0.2="ISP1/Gold")
SNMP SET (10.0.0.2="ISP1/Gold")
LDAP LOOKUP OF "ISP1/Gold"
CHOOSE PUBLIC IP
FROM NATI POOL
ADD NAT ENTRY
10.0.0.2=
130.42.61.7
ADD NAT ENTRY
10.0.0.2 =
130.42.61.7
10.0.0.2 PRIVATE
130.42.61.7 PUBLIC
MAC YYYYYY
QoS=HIGH
DNS=YES
"ISP1/Gold POLICY" NAT GROUP 1
QoS HIGH
DNS=YES
LDAP RESPONSE OF "ISP1/Gold"
SNMP SET (10.0.0.2=130.42.61.7)
HTTP REGISTRATION
SESSION END
SNMP SET (10.0.0.2=130.42.61.7)
REGISTRATION SESSION WITH
SERVER ENDS. USER INSTRUCTED
TO REBOOT THEIR PC

FIG. 3A

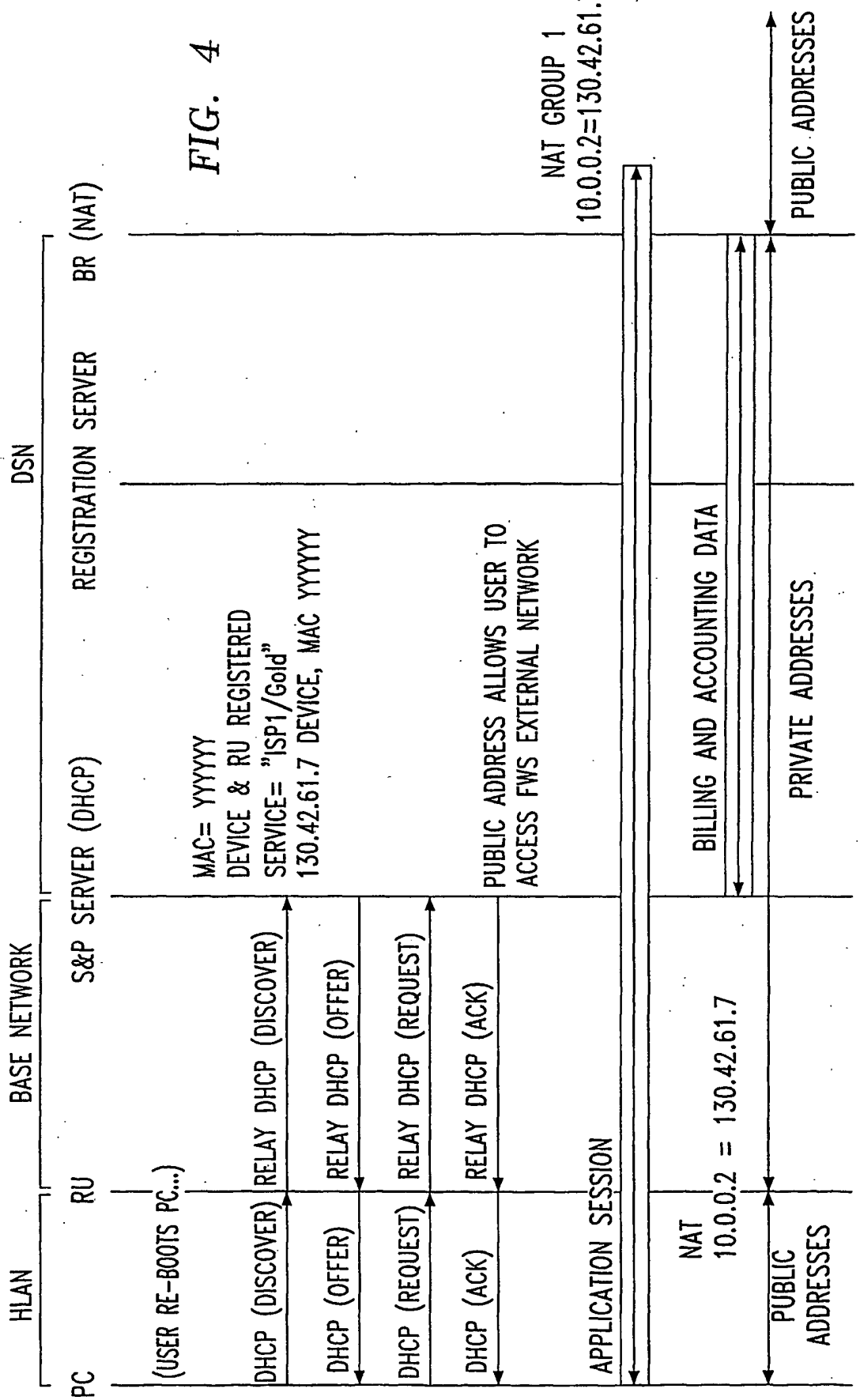

HLAN
BASE NETWORK
DSN
PC
RU
S&P SERVER (DHCP)
REGISTRATION SERVER
BR (NAT)
(USER RE-BOOTS PC...)
DHCP (DISCOVER)
RELAY DHCP (DISCOVER)
MAC= YYYYYY
DEVICE & RU REGISTERED
SERVICE= "ISP1/Gold"
130.42.61.7 DEVICE, MAC YYYYYY
DHCP (OFFER)
RELAY DHCP (OFFER)
DHCP (REQUEST)
RELAY DHCP (REQUEST)
DHCP (ACK)
RELAY DHCP (ACK)
PUBLIC ADDRESS ALLOWS USER TO
ACCESS FWS EXTERNAL NETWORK
NAT GROUP 1
10.0.0.2=130.42.61.7
APPLICATION SESSION
BILLING AND ACCOUNTING DATA
NAT
10.0.0.2 = 130.42.61.7
PRIVATE ADDRESSES
PUBLIC
ADDRESSES
PUBLIC ADDRESSES

FIG. 4

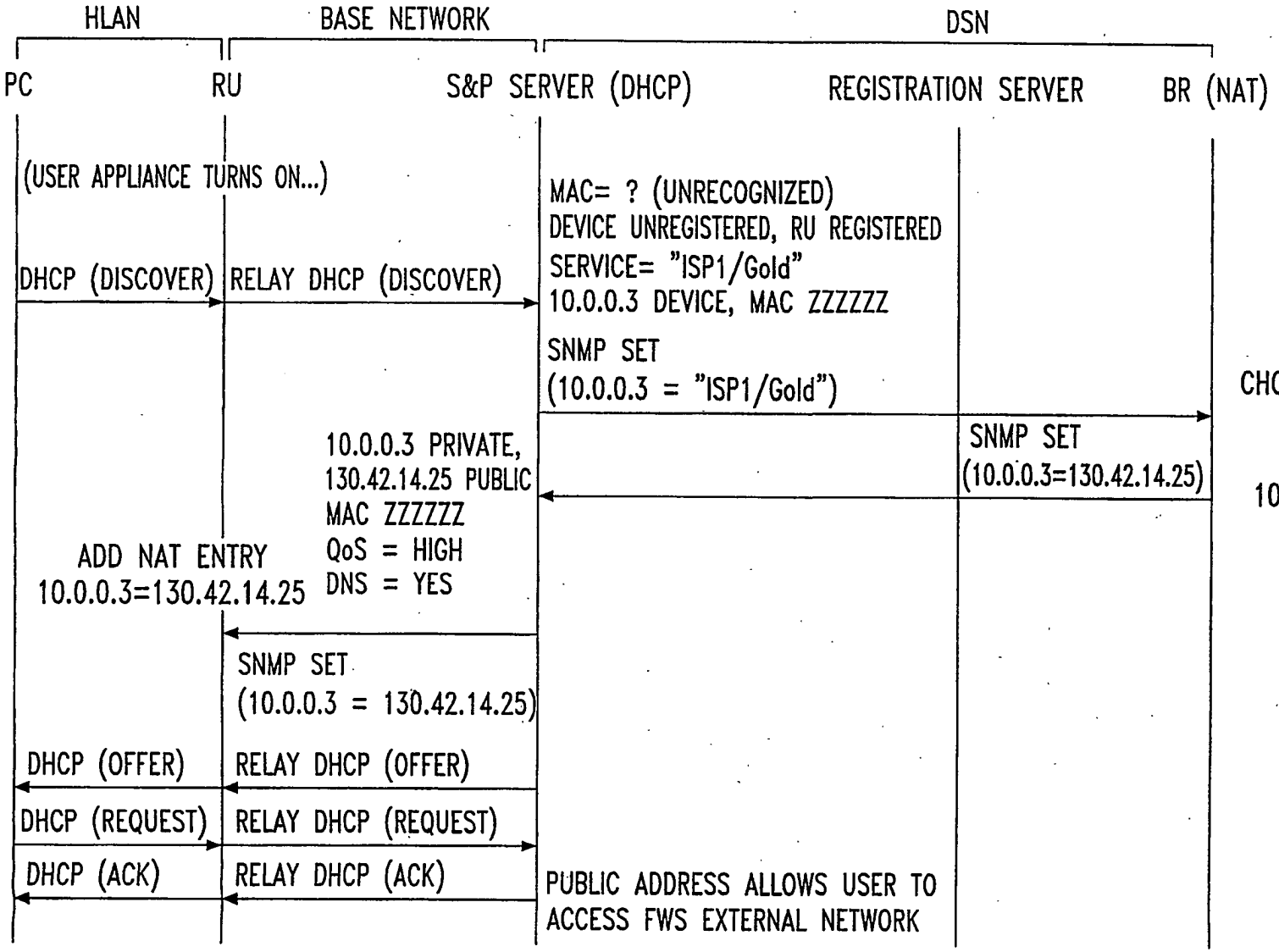
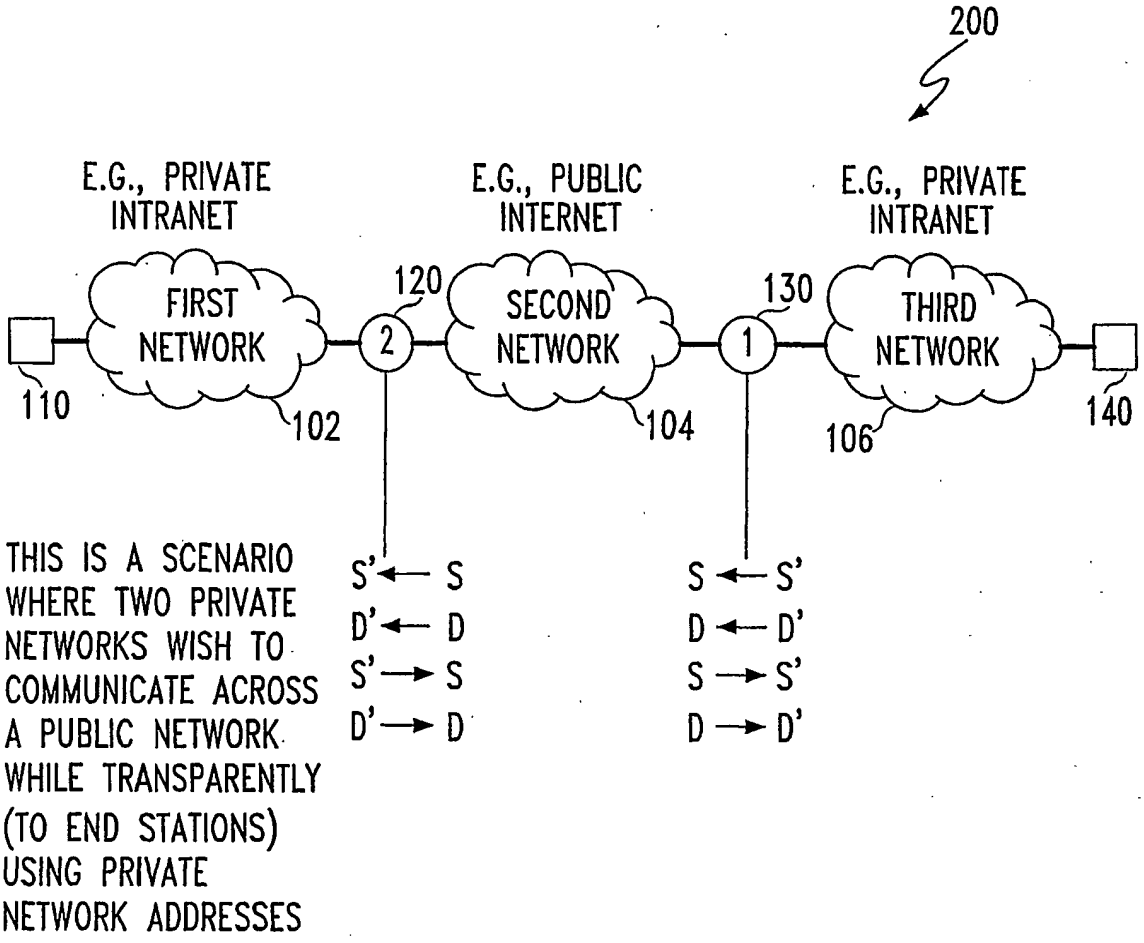

HLAN
BASE NETWORK
DSN
PC
RU
S&P SERVER (DHCP)
REGISTRATION SERVER
BR (NAT)
(USER APPLIANCE TURNS ON...)
MAC= ? (UNRECOGNIZED)
DEVICE UNREGISTERED, RU REGISTERED
SERVICE= "ISP1/Gold"
10.0.0.3 DEVICE, MAC ZZZZZZ
DHCP (DISCOVER)
RELAY DHCP (DISCOVER)
SNMP SET
(10.0.0.3 = "ISP1/Gold")
CHOOSE PULBIC IP FROM
NAT1 POOL
ADD NAT ENTRY
10.0.0.3=130.42.14.25
SNMP SET
(10.0.0.3=130.42.14.25)
10.0.0.3 PRIVATE,
130.42.14.25 PUBLIC
MAC ZZZZZZ
QoS = HIGH
DNS = YES
ADD NAT ENTRY
10.0.0.3=130.42.14.25
SNMP SET
(10.0.0.3 = 130.42.14.25)
DHCP (OFFER)
RELAY DHCP (OFFER)
DHCP (REQUEST)
RELAY DHCP (REQUEST)
DHCP (ACK)
RELAY DHCP (ACK)
PUBLIC ADDRESS ALLOWS USER TO
ACCESS FWS EXTERNAL NETWORK

FIG. 5



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[D,S]= GLOBALLY UNIQUE IP ADDRESSES
[D',S']= NON GLOBALLY UNIQUE IP ADDRESSES

ASSUMPTIONS:

- FIRST NETWORK AND THIRD NETWORK USE NON GLOBALLY UNIQUE ADDRESS

- SECOND NETWORK USES GLOBALLY UNIQUE ADDRESSES

FIG. 6